Method for producing a three-dimensionally formed armoring component for vehicle bodies

The invention relates to a method for producing a three-dimensionally formed armoring component for vehicle bodies by the production of sheet metal preforms from hardenable steel, with the thermal pre-treatment of these steel sheet blanks, the heating speed and heating temperature being selected until the austenitic state dependent on alloy content is reached, and with subsequent press forming and hardness treatment of the formed armoring components. Technical solutions of this kind are required, for example, in the motor vehicle construction of armored limousines.

In the production of special protective vehicles, armorings are used which are inserted into the outer planking of vehicle bodies. Since high-grade steels are difficult to process, these armorings are mostly designed as welding subassemblies. The known susceptibility to distortion and the considerable temperature sensitivity, which may bring about a decrease in strength even above a temperature of 200°C, often lead to crack formations and stress problems in the direct weld seam region and to strength problems in the heat influence zones. These undesirable effects rise with an increasing content of alloying elements and armoring hardness. This leads to an impairment of the protective effect required.
The production of three-dimensional components by hot forming with subsequent heat treatment is known.
Thus, DE 198 21 797 C1 discloses a method for the production of hardened parts from steel. This method serves particularly for obtaining preliminary products which, for example for the production of rolling bearings and transmission parts, on the one hand, are particularly resistant to fatigue, have a high load-bearing capacity and are wear-resistant and, on the other hand, are to be capable of being produced particularly adaptably in the interests of minimal mechanical remachining. For this purpose, an air-hardening steel is used, which is

obtained after heating to at least 1100°C first with hot forming to a temperature of at least 800°C and then with cooling by means of air to about 280°C, at the same time with thermomechanical treatment by calibration, subsequent cooling in air to room temperature and final expansion treatment at a temperature of 150 to 250°C.

Furthermore, US 5, 454, 883 A discloses a method, with the aid of which hardened steel plates are produced in that the heating rates during thermal treatment and the holding times at selected treatment temperatures are optimized. Moreover, in a variant, this technical solution suggests dispensing with calibration during the cooling of the components.

The common shortcoming of the known technical solutions is that they are unsuitable for the production of three-dimensionally formed sheet metal preforms from hardenable steel sheets, particularly when a cutting surface retreatment of the hardened sheet metal preforms is to be avoided. To that extent, the known technical solutions for the production of semifinished products, such as are required in mechanical engineering for the production of high-strength steel structures, highly load-bearing structural machine elements in the form of rolling bearing parts and transmission parts, are unsuitable for the production of three-dimensionally formed armoring components for vehicle bodies.

The object, therefore, is to provide a technical solution, with the aid of which the shortcomings of the known prior art are overcome. In particular, a method is to be developed which is suitable for the production of armoring components for vehicle bodies, while avoiding weak points in the armored region. The armoring components are to be capable of being produced as comparable welded structures with repeating accuracy and markedly lower dimensional tolerances along with minimized remachining requirements.

The object is achieved, according to the invention, by means of the features of claims 1 and 2. Advantageous refinements

are described in the subclaims. Accordingly, the method provides for the production of a three-dimensionally formed armoring component for vehicle bodies by the production of sheet metal preforms from hardenable steel. For this purpose, the steel sheet blanks are thermally pretreated, the heating speed and heating temperature being selected such that the austenitic or partly austenitic state dependent on alloy content is reached. In the austenitized state, the predominant part of the alloying elements contained in the material of the steel sheet blank is dissolved in the austenite. During austenitization, the heat treatment time is selected as a function of the carbon content, of the quantity and type of alloying elements and of the sheet thickness, such that scaling, skin decarburization and grain growth are minimized. Thereafter, press forming takes place, with subsequent heat treatment, if necessary, as a result of which the desired three-dimensionally formed armoring components are obtained.

The method provides for carrying out the hot forming and quench hardening of the steel sheet blanks in one operation. The austenitized steel sheet blank is formed by means of a press die as immediately as possible, preferably still in the austenitic or partly austenitic state, and, as a result of the high cooling rate which is aimed at, the desired hardness structure in the formed steel sheet blank is achieved.

The required critical cooling rate is in this case selected such that a hardness structure is obtained.

After the closing of the press die, the formed component is held in full-area contact with the press die. The full-area contact of the formed steel sheet blank with the press die ensures the avoidance of deformations as a result of thermal stresses up to the partial or complete structural transformation of the formed steel sheet blank and serves for producing the required hardness structure in all the part regions of the armoring component generated. Weak points within the armoring component are consequently reliably avoided.

The cooling of the formed component is an integral part of the hardness treatment and therefore takes place in the closed

press die.

Preferably, the forming in the press die takes place such that, during a pressing operation, with the formed steel sheet blank bearing over its full area against the impression of the press die, the rate of cooling of the austenitized or partly austenitized steel sheet blank is as far as possible above the critical cooling rate.

Alternatively to this method variant, it is possible, furthermore, that the austenitized steel sheet blank, after being inserted into the press die, is first formed and held in complete contact with the press die, the press die being cooled at least to approximately 70°C before the forming process. After the forming process, the further cooling of the formed steel sheet blank is carried out, with the press die open or outside the press die in the ambient air. In this case, it is assumed that the shock-like cooling of the austenitized formed steel sheet blank in the precooled press die leads not only to the formation of the fundamental hardness structure, but also to a sufficient dimensional stability of the three-dimensional armoring component produced. In this case, the press die can be used at a higher frequency for the production of components with repeating accuracy.

Preferably, the steel sheet blanks used are sheets of hardenable and maraging steels.
The method provides for the initial hardness of the armoring steel during hardening in hardening oil to be higher than 45 HRC or for the hardness after artificial ageing to be higher than 45 HRC.
Three-dimensionally formed armoring components with high dimensional accuracy are obtained, in particular, in that, after the forming operation, the press die is held closed for a period of time of 50 to 500 seconds until the desired cooling temperature is reached. As a result, the component is held in calibration up to the complete formation of the

hardness structure, as a consequence of which deformations due to thermal stresses can be largely ruled out.
The cooling rate via the contact of the formed steel sheet blank with the press die is influenced in that the press die consists of highly thermally conductive material, for example steel, and/or can be cooled by coolants, preferably, for example, water, ammonia and/or compressed air.

It is possible to subject the cooled and formed steel sheet blanks to final heat treatment in the form of an expansion and/or tempering process, annealing or age-hardening treatment.

Alternative to this, measures, such as hardening, age hardening or artificial ageing, are also possible as thermal retreatment procedures, depending on the alloy composition. These measures serve for compensating possible uneven distributions of the degrees of hardness in the component and consequently to rule out unreliability in safety against the effects of bombardments or explosions. The thermal distortion occurring during thermal retreatment is known to be about only 10% of the armoring components produced by means of welding technology.
It is particularly advantageous that hot forming and quench hardening of the austenitized or partly austenitized steel sheet blanks are carried out in one operation.

The advantages of the invention, when combined, are that, for the special case of the production of three-dimensionally formed armoring components for vehicle bodies, specific requirements regarding the production of hardened steels, such as are known for the production of tools or semifinished products, do not have to be fulfilled. This refers, for example, to resistance to rolling fatigue, wear resistance or the fatigue limit under alternating stresses.
It may be assumed that the body of a vehicle of the special protection class is distorted completely or at least in respect of the loaded armoring components after being

subjected for the first time to load by bombardment or explosion. In light of these particular requirements, the armoring components to be produced must have, in particular, continuous or full-area quality and, if possible, not require a mechanical remachining of the surface of the three-dimensionally formed armoring component. The proposed method takes these particular requirements into account to a high degree. As compared with known welded structures, three-dimensionally formed armoring components of high quality are obtained in a comparatively simple way by conjoining a hot forming process with a hardening process, starting from sheet blanks which have previously been pretreated in an austenitized or partly austenitized state.

In accordance with the desired protection class, characterized by defined bombardment safety and possible safety against explosions, the aim is to achieve the required heat treatment parameters.

Some annealing steels for use in protective class VR6 in this case, by the application of the proposed method, achieve, even without subsequent heat treatment, all the protective requirements, including safety against explosions by hand grenades of the type DM51, without splinter outbursts on the rear side of armoring elements.

In the design of the press dies, care must be taken to ensure that sufficient heat dissipation can be ensured at every point on the formed steel sheet blank. Furthermore, the flow properties of the material must be borne in mind, so that, during the forming operation, the component comes to bear under uniform surface pressure completely and uniformly against the impression of the die and thinnings of the material thickness are avoided. To stabilize the component during heat treatment, beads or stabilizing forms extending continuously may be embossed in the blank. After the hot pressing or possible heat treatment, the final form of the component is cut out by means of a laser or preferably a water jet.

By means of the proposed method, then, three-dimensionally

formed armoring components for different protection classes can be produced, and their wall thickness may even amount to more than 10 mm. By hot forming, then, armoring components for vehicle bodies can be implemented, which it has hitherto been possible to produce only as complicated welding structures with ballistic weak points in the weld seam region.
Owing to the high process reliability, the large-series use of the method for the production of three-dimensionally formed armoring components with high dimensional accuracy is possible.

The invention will be explained in more detail below by means of implementation examples.

Implementation Example 1:
A steel sheet with a thickness of 6.5 mm has the following content of alloying elements:

0.5%	C
1.1 - 1.3%	Ni
1.0 - 1.5%	Si
0.5 - 0.6%	Mn
0.1 - 0.5%	Mo.

From this steel sheet, a sheet blank is obtained and is heated to an austenitizing temperature in the amount of 950°C. In this state, the sheet blank is inserted into the press die and is formed as a result of the closing of the press die. Within a total of 300 seconds, the quench cooling of the formed steel sheet blank to the die temperature takes place. The die may in this case be cooled by coolant. The closing pressure of the press die is maintained over the entire cooling time.
Subsequently, heat treatment takes place by annealing to the quality HRC 50. The three-dimensionally formed armoring component corresponds to bombardment class VR6, this having been demonstrated by bombardment tests.

Implementation Example 2:

A steel sheet blank with a thickness of 6.5 mm has the following fractions of alloying elements:

0.25 - 0.4 %		C
0.0 - 1.0 %		Ni
0.2 - 0.4 %		Si
0.0 - 2.0 %		Mn
0.0 - 0.55%		Mo
0.0 - 1.1 %		Cr.

This steel sheet blank is heated to an austenitizing temperature in the amount of 970°C and is immediately inserted into the press die and formed as a result of the closing of the press die. The press die has previously been cooled to approximately 70°C. As a result of the shock-like cooling due to the optimized dissipation of a large part of the heat from the steel sheet blank to the press die, the formation of a sufficient hardness structure occurs. Consequently, after the conclusion of the forming operation, the press die can be opened and the further cooling of the three-dimensionally formed armoring component can be carried out at room temperature.

A subsequent heat treatment is dispensed with. The three-dimensionally formed armoring component obtained corresponds to bombardment class VR6, this having been demonstrated by bombardment tests.